CHAPTER 7

Nutrient and Algal Criteria Development

7.1 INTRODUCTION

This chapter addresses the details of developing scientifically defensible quantitative criteria for nutrients, algae, and measures of water clarity (referred to hereafter as nutrient criteria). The chapter is divided into eight sections: (1) role of the RTAG; (2) classification; (3) descriptive background information; (4) approaches to criteria development; (5) evaluation of proposed criteria; (6) criteria modification; (7) EPA, State, and/or Tribal responsibilities under the Clean Water Act (CWA); and (8) implementation of nutrient criteria into water quality standards. The five elements of criteria development described in the Executive Summary and Chapter 1 are integrated herein, and additional information relevant to criteria development is provided.

As explained in Chapters 2 and 3, estuaries and coastal waters are especially complex ecosystems where it is often difficult to distinguish the effects of anthropogenic nutrient enrichment from natural variability primarily because of intervening physical processes and their interaction with biological (e.g., grazing; Cloern 1982) and chemical (e.g., flocculation and sedimentation) processes (Malone et al. 1996, NRC 2000). The individual nature of many of these ecosystems presents a particular challenge for criteria development. The ideal goal is to establish nutrient criteria that are protective during periods when estuaries and coastal ecosystems are most vulnerable to nutrient enrichment and that protect designated uses. It is important to understand that designated uses may be met but some nutrient-based impairment may have occurred. In such cases, it is also desirable to have restoration goals in mind whose objective is to restore the original ecological integrity, at least as represented by the reference conditions and criteria. This information helps determine if new designated uses are appropriate.

If a shallow estuary is dominated by point sources of nutrients, then low freshwater flow periods might be times of greatest vulnerability because of limited flushing. For a deep estuary under the same situation, weak density stratification may set up conditions where the algae spend considerable time below the euphotic zone and, hence, bloom development is minimized. Now, consider the situation where these two estuaries are dominated by nonpoint sources of nutrients. The low flow period would likely contribute lower nutrient loads to both types of estuaries and with weaker density stratification the algal bloom potential might be substantially lowered (see Chapter 2). It is also extremely difficult to establish nutrient criteria for episodic events, either hurricanes or drought periods. The reference condition and consistent reference site records, however, make it possible to adjust the criteria accordingly to address these intervals.

In this manual, the elements of criteria development are sequenced and emphasized somewhat differently from those described in the two published freshwater manuals. Because of the relatively high individual nature of estuaries and coastal waters, the role of the regional technical assistance groups (RTAGs) is enlarged and historical data become especially important in development of nutrient criteria. Figure 7-1 provides a visual perspective of the elements that should be integrated to arrive at a criterion.

7.2 ROLE OF REGIONAL TECHNICAL ASSISTANCE GROUPS

Expert evaluations are important throughout the criteria development process. The role of the RTAG in criteria development for estuaries and coastal waters has an added dimension over that applicable to lakes and reservoirs and rivers and streams. In the latter case, most of the data used in development of criteria recommendations resided in national electronic data sets (e.g., STORET) collected by State and Tribal agencies. The RTAGs helped review these data for duplication and outliers. They also encouraged States and authorized Tribes to submit additional data to STORET. Under these circumstances, EPA developed criteria recommendations based on frequency distributions (U.S. EPA 2000a,b). However, for most estuaries and coastal waters, the majority of relevant data have been collected by universities and other organizations (e.g., NOAA, Minerals Management Service, USGS); many of their data are not entered into STORET. It is expected that regional RTAGs will likely be considerably more knowledgeable about the data veracity and applicability for criteria development in their region. In addition, it is anticipated that the regional RTAGs will have the knowledge and access to other local scientific expertise to assist in the sampling design and collection of additional data. These considerations lead to the expectation that the RTAGs will have a larger role in the development of protective nutrient criteria for estuarine and coastal waters.

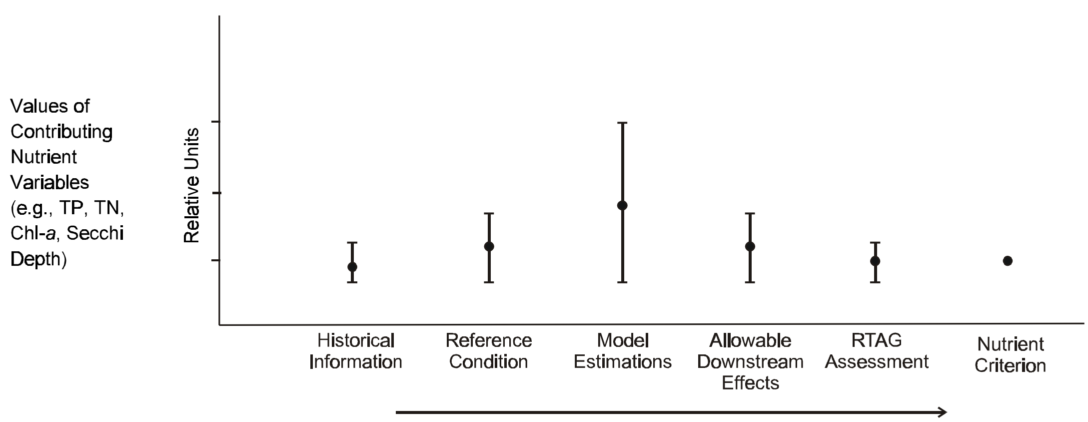

Figure 7-1. Generalized progression and relationship of the elements of a nutrient criterion.

Because of the tendency of estuaries and coastal waters to exhibit a high degree of individuality relative to nutrient susceptibility, little predictive success has been demonstrated in using published values of nutrient concentrations or nutrient impairments. However, experience with an individual estuary or coastal water system may demonstrate a general range of algal biomass accumulation that leads to hypoxia at a known level of enrichment. This type of assessment often requires several to many years of observation and measurement and is an example of incorporating the RTAG experience in the criteria development process.

EPA expects to continue to lead the effort to identify potential estuarine and coastal waters for the development of nutrient criteria and fund the overall data collection and analysis.

7.3 CLASSIFICATION

Classification is a pivotal step in the process of developing criteria. Physical classification of waterbodies for nutrient criteria development reduces variability in ambient measurements as the reference conditions and nutrient criteria represent and reflect a relatively similar natural state. Classification helps ensure that appropriate comparisons are made among comparable waterbodies so that the variables measured are influenced as little as possible by dissimilar inherent characteristics. This will facilitate appropriate application of criteria through their implementation.

In contrast to rivers and lakes, physical classification of estuarine and coastal waters is scale-sensitive (Giller et al. 1994) and may not be as predictable of nutrient enrichment effects or be as useful for generalizations about effects among estuarine systems. Classification nonetheless can provide improved understanding of the processes that contribute to ecosystem susceptibility and variability in the expression of nutrient effects. Classification may have valuable applicability at smaller physical scales within larger estuarine and coastal ecosystems (e.g., embayments; subestuaries and estuaries discharge plumes). Classification based on salinity gradients, circulation patterns, depth, and flushing within larger estuarine and coastal systems should also prove useful, especially in correlating the different biological communities at risk to nutrient overenrichment.

7.4 DESCRIPTIVE BACKGROUND INFORMATION

Estuarine Watershed Characterization

One of the keys to understanding nutrient enrichment problems in waterbodies is an environmental characterization of the watershed from a historical perspective. Such investigations may provide insights into the potential for confounding cause and effect relationships (e.g., nutrient, not herbicides as the primary cause of the SAV decline in Chesapeake Bay.) Historical changes in land use, land cover, and population demographics may correlate with increased anthropogenic-based nutrient enrichment and major changes in downstream water quality and biological community structure.

Farm acreage, crop types, and fertilizer application rates also provide useful information to assess the potential historical magnitude in nonpoint source nutrient loading to estuarine systems. Atmospheric plumes that result in nitrogen deposition should also be assessed as they may help explain an increased nitrogen load to coastal waters beyond that attributed to local land use activities. This also is a situation where reference sites, if available, will help the manager distinguish atmospheric from local anthropogenic causes of overenrichment. Conversely, increases in forest coverage and soil banking of agricultural lands may help explain potential decreases in nitrogen and phosphorus loading to estuaries and coastal waters.

Within Estuarine System Characterization

Changes within estuarine systems that influence basic hydrography should not be overlooked. For example, opening new passes, and later deepening them in several Gulf of Mexico estuaries during the early part of the 20th century (e.g., Perdido Bay, Alabama/Florida, and Choctahatchie Bay, Florida) apparently modified estuarine circulation resulting in strengthened density stratification leading to enhanced potential for hypoxia (Livingston 2001a). Also, major changes in freshwater supplies should be considered as a potential factor that can modify estuarine susceptibility to nutrient enrichment.

The use of marine sediment cores is another tool to assist in assessment of nutrient enrichment patterns in coastal waters (Brush 1984). These analyses are relatively expensive to perform but appear more frequently in the literature because of the numerous important insights they provide. They can provide estimates of sedimentation rates and initiation of anoxia, changes in algal community structure, initiation of the loss of SAV and other responses to nutrient enrichment. This temporal picture is important in setting approximate timelines when nutrient enrichment may have been a major cause of biological impairment. However, correlation does not necessarily equate to causality (Havens 1999).

It is also important to attempt to collect long-term (e.g., multiple decades) fisheries landings data as many stakeholders need to be appraised of whether such landings data are associated with nutrient enrichment. Such analyses often prove to be difficult because information on catch per unit effort that helps normalize for variable fishing pressure, is difficult to obtain. A change in fishery yield may be confounded by overfishing, as well as the role of increased or decreased primary productivity. Increased bottom water hypoxia related to overenrichment may explain the loss of benthic habitat for bottom-dwelling marine life (e.g., flounder and croaker and benthic infauna that serve as fish food).

Historical decreases in water column visibility from nutrient-driven algal blooms (phytoplankton and macroalgae) may explain reductions in water-borne recreation (e.g., swimming); however, human perceptional responses are often subjective and other factors such as user conflicts may also be involved. Reduced visibility may also be related more to inorganic suspended sediments then nutrients. So, both chlorophyll *a* records and total suspended sediment concentrations, preferably measured from the same local water mass, may be required to establish nutrient enrichment (Gallegos 1994). Such analyses need to be assessed with freshwater flow records because of potential co-linear effects that complicate interpretation of cause and effect relationships.

The above measurements performed as part of a general characterization may help relate nutrient enrichment effects and thresholds to existing and designated uses and identify any reference systems that are minimally impacted by nutrient pollution. Such information may enter directly into predictive water quality models or serve as indirect collaborative information contributing to a "weight of evidence" analysis.

7.5 ELEMENTS OF NUTRIENT CRITERIA

Reference Condition

Chapter 6, beginning with Table 6-1, describes several approaches that can be employed to determine the ambient minimally impacted nutrient condition of the water resource. The significance of this reference condition to nutrient criteria development cannot be overstated. It represents the determination of the existing, presently attainable nutrient water quality of the estuarine or coastal waters of concern.

The selection of the method for reference condition determination in this manual involves more options than previous guidance manuals because so many estuaries are reported to be unique and/or severely degraded, thus requiring an array of alternative approaches to approximate reference conditions in the absence of acceptable reference sites. In selecting from the different approaches, the resource manager should strive for the most direct measurement of the resource and with the least number of intermediate interpretative steps to a determination. Of equal importance in this process are in situ reference sites and supporting data showing the system response to the nutrient increases. The best of both these worlds is a set of reference sites documenting an optimal nutrient condition as well as response data confirming that system degradation occurs at levels beyond this measure, which also corresponds to the EPA regional reference condition for that area and class of waters. Failing this, the manager should seek the greatest approximation possible and a sufficient understanding of the divergence to be confident of the reference values determined.

Even though the reference condition is salient to nutrient criteria development, it should not be interpreted as the only necessary element. It should be interpreted in light of the historical condition of the resource and projections of its future potential.

Historical Information

Knowledge of antecedent conditions is particularly important in the case of estuarine waters, where causal relationships are often confounding and existing reference sites compromised. In such cases the historical data may not only qualify present information, they may, in fact, be the requisite reference condition demonstrating to the manager and RTAG not only previous nutrient quality, but least impacted conditions as well.

Models

In addition to computer modeling to help determine reference conditions, models may be used both to estimate nutrient loads and load reductions to achieve a targeted nutrient regime in the receiving estuarine and coastal waters systems. Various models are available (Chapter 9) that estimate nutrient erosion from different land uses, riverine transport of nutrients, and estuarine effects including hypoxia and chlorophyll *a* concentrations. These models are typically expensive to calibrate and verify, but in large estuaries and coastal ecosystems their application can be cost-effective when costly nutrient control decisions are involved. A coupled nutrient transport and hydrodynamically coupled algal nutrient uptake and growth model provides the ability to address “what if scenarios” of nutrient load versus level of biological impairments (see Chesapeake Bay Case Study and web site).

Statistical models can be used to help separate effects of nutrient loading from estuarine physical processes as determinants of increases in system response variables (e.g., chlorophyll *a* concentrations; Harding and Perry 1997). Effects of nutrient enrichment are inferred by a process of elimination when the suspected physical forcing functions are de-trended in the analyses and are inferred not to explain the variability. Box models, using salinity as a tracer of water masses, are useful in assessing net non-tidal physical circulation, hydraulic residence times, the effect of river flow on residence time versus seaward higher salinity processes, and extent that nutrient sources are conserved within an estuarine region or transported seaward (Hagy et al. 2000). Dettmann (in press) used a regression modeling technique to compare the degree of nitrogen export of a variety of estuarine systems. Boynton et al. (1996) used a box model to mass balance nitrogen and phosphorus in Chesapeake Bay and calculated net transport from the Bay of nitrogen and phosphorus, sedimentation, amount tied up in plants and the amount of nitrogen lost from the Bay through denitrification. Properly applied box and regression models are relatively inexpensive to construct and can provide useful information to the scientist and water quality manager.

Antidegradation Policy and Attention to Downstream Effects

A critical requirement for the use of reference conditions associated with nutrient criteria is the EPA antidegradation policy, which protects against incremental deterioration of waterbodies and reference conditions. An observed downward trend in the conditions of reference sites cannot be used to justify relaxing reference expectations, reference conditions, and the associated nutrient criteria. Once established, nutrient criteria should only be refined in a positive direction in response to improved conditions. Without antidegradation safeguards, even the establishment of reference conditions and nutrient criteria could still allow for continual deterioration of water quality.

To combat this, the States should implement an effective antidegradation policy that promotes continually improving conditions. As an example, Maine has an antidegradation policy that requires that waterbodies remain stable or improve in trophic state (Courtemanch et al. 1989, NALMS 1992). The RTAG should assume a comparable sense of antidegradation responsibility.

Estuaries that supply nutrients to relatively static coastal waters may require more stringent nutrient criteria, not only to protect estuarine designated uses (e.g., “fishable and swimmable” conditions), but the water quality of coastal shelf waters. At present, there are little data to assess whether U.S. estuaries are supplying nutrients to coastal shelf waters at levels that are causing widespread harm, except in the case of world-class rivers (e.g. Mississippi River Plume on LA/TX shelf). Locally, river-dominated estuaries with open passes to the coastal shelf supply nutrients at levels that may increase secondary productivity of valued fisheries (Sutcliffe et al. 1977), but the potential threshold for overenrichment effects in such cases is generally still poorly understood. If the RTAG determines that estuarine nutrient criteria may be expected to fall between the existing present nutrient concentrations or load and the reference condition determined from similar unimpaired systems or from a historical load and response relationship. It is then up to the States and Tribes to adopt the criteria into 303(c) water quality standards.

The RTAG

Assimilation of all of the above information is the responsibility of the RTAG when developing ecoregional nutrient criteria and when reviewing State or Tribal nutrient criteria as part of its role to assist EPA.

The RTAG should work with the States to develop a monitoring program that would evaluate the status of the reference systems, the possible future negative anthropogenic nutrient effects, and the condition of the estuary and coastal receiving water. A well-designed monitoring program should provide data to assess whether there is incremental deterioration of the subject waterbodies and reference conditions.

7.6 HYPOTHETICAL EXAMPLES OF NUTRIENT CRITERIA DEVELOPMENT DELIBERATIONS

To help illustrate the role and responsibility of the RTAGs, an abbreviated hypothetical illustration of nutrient criteria development follows for a river-dominated estuary that has a relatively deep channel with moderate density stratification, and well-developed seagrass meadows located in the shallow waters. The estuary is located in the northern Gulf of Mexico. The estuary often borders on both nitrogen and phosphorus limitation with nitrogen limitation occurring more frequently during the summer. The nitrogen sources have been and continue to be primarily nonpoint sources in headwater streams and point sources near the pass to the Gulf. Tidal action is minimal. The focus for this illustration is on nitrogen criteria.

Scenario

In the subject nitrogen-limited estuary no existing areas qualified as a reference condition and no meaningful analogs of the estuary were available to apply the spatial-based frequency/percentile approach to reference conditions applied to lakes (e.g., the 25/75 percentile approach; see Lakes and Reservoirs Nutrient Guidance Manual, U.S. EPA 2000a). The historical nutrient concentrations were plotted over time by classifying the summer estuarine salinity zones based on the 30-year average into tidal fresh and brackish (0-5 psu), mesohaline (5-18 psu) and polyhaline (18-30 psu). The concentrations were consistent with a calculated nutrient load and estuarine physical hydrodynamic model. Additional analysis demonstrated that the system was most vulnerable to average summer freshwater inflows. Flushing in the estuary was determined to be on the order of one month on average during the summer under average freshwater flow conditions so the physical potential was high for phytoplankton bloom buildup.

A 50 µM TN reference condition was determined by plotting TN concentrations for the mesohaline zone from 1970 to 2000. Because nutrient data were few for the estuary prior to 1970 and most of the data were collected for the mesohaline zone, a decision was made to select the 1970 summer average TN value as the reference condition with application for the mesohaline zone. Only an occasional bottom channel hypoxia occurred in the summer of 1970 and seagrass meadows were growing to a depth of 1 to 2 meters. By 1980, the average summer TN concentrations had increased to 60 µM when it became apparent from field monitoring that major loss of seagrass acreage was documented, hypoxia volumes had doubled, and hypoxia-laden water had consistently reached the deep-channel/shallow water shelf break. By 1980, seagrasses grew on average only to 0.5 meter depth. Some sediment core evidence indicated that seagrasses in 1950 grew at a depth of 2 to 3 meters but the nutrient concentrations and loading information were much weaker than for the 1970-2000 period. The reference condition of 50 µM TN suggests a gradual rise upward in ambient TN, from an estimated average 20 µM TN 100 years ago, with a projected further upward trend indicated by use of demographic, land use, and hydrological models. It was determined that a significant loss of ecological integrity had likely occurred prior to 1950. The RTAG, therefore, concluded that setting a criterion any higher than the present reference condition would eventually lead to an unacceptable trend in water quality degradation due to expected development increases for this part of the estuary. If the model projections are accurate, any increased load implied by raising the criteria above reference levels will hasten nutrient overenrichment problems. Some on the RTAG argued that the criterion should be set at 54 µM TN but the final consensus was to be somewhat conservative. The RTAG therefore concludes that it will be prudent to set the criterion at 50 µM TN (see Figure 7-2).

7.7 EVALUATION OF PROPOSED CRITERIA

The RTAG will provide expert assessment of proposed criteria and assure that criteria protect designated uses. Criteria will need to be verified in many cases by comparing criteria that apply across State and Tribal borders. In addition, attention will need to be paid to downstream effects and designated uses,

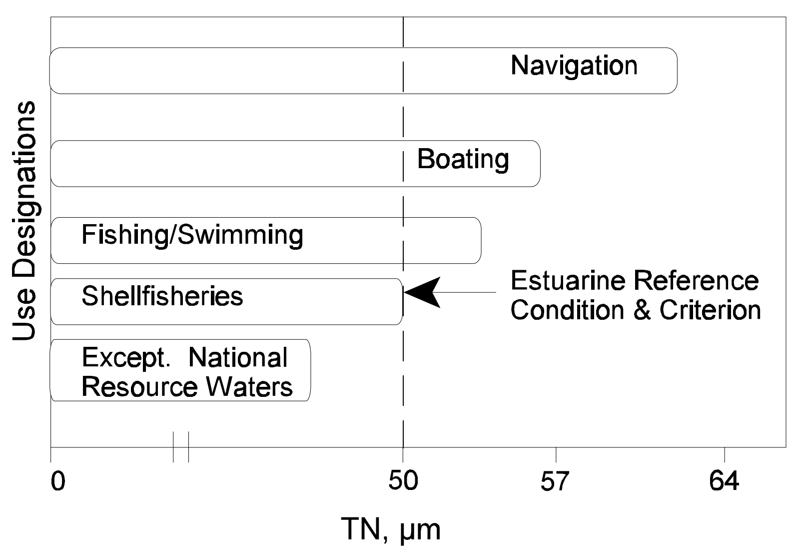

Figure 7-2. Hypotetical illustration of developing a TN criterion in an estuary.

especially in large estuaries that are shared by two or more States or Tribes. Criteria recommended by the RTAG can be adopted by the State or Tribe and approved by EPA if evidence is presented that assures no adverse effects will result downstream (e.g., criteria developed for tidal freshwaters may not be stringent enough to protect uses located at higher salinities.) In estuaries, a consideration, not typical of streams and lakes, is one where the life cycle of anadromous and semi-anadromous fish species must be considered as well as marine spawners that utilize estuaries as nursery areas. The RTAG may need to consult with neighboring Regional RTAGs in regions where estuaries are shared.

At present, EPA's Office of Water is developing a policy to address effects from nutrient transport that causes water quality problems at downstream estuarine sites including river systems that deliver nutrients from far inland to coastal tidal systems. If downstream designated uses are not protected by a proposed criterion, then the river or stream criterion must be modified accordingly.

Guidance for Interpreting and Applying Criteria

A critical step in the criteria development process is to assess how realistically criteria can be implemented into standards that are accepted by the public. It should be realized that today's designated uses are not those that would be applicable in many estuaries at the turn of the century or in some cases even several decades ago. Many estuaries have lost important fisheries that may not be easily recovered if at all. For example, sturgeon are rare in many estuaries today when they were abundant decades ago in several east coast estuaries. It is doubtful that the nutrient relationship for sturgeon growth and survival is adequately known except for obvious factors such as hypoxia. The RTAG should make some judgements about designated uses as exemplified by the sturgeon example that significantly improves nutrient-based degraded water quality in terms of "fishable and swimmable" but maintains an important degree of realism.

Do the Criteria Protect Designated Uses?

Section 303(c) of the CWA as amended (Public Law 92-500 [1972], 33 U.S.C. 1251, et seq.) requires all States and authorized Tribes to establish designated uses for their waters. EPA's interpretation of the CWA requires that wherever attainable, standards should provide for protection and propagation of fish, shellfish, and wildlife and provide for recreation in and on the water (section 101(a)). Note: this is the secondary goal of the Act; the primary goal being the protection and restoration of the physical, chemical, and biological integrity of the Nation's waters, and zero discharge of pollution. Other uses identified in the Act include industrial, agricultural, and public water supply. However, no waters may be designated to be used as repositories for pollutants (see 40 CFR 131.10(a)). Each waterbody must have criteria that protect and maintain the designated use of that water.

Also discussed below are general guidelines for developing criteria to protect selected designated uses. The values included here are *not* intended to represent proposed EPA or State estuarine and coastal waters nutrient criteria. Rather, they are simply guidance and illustrate ranges of parameters associated with the impairment of some designated uses in some States and Tribes. Criteria to protect these uses should be developed on a site-specific basis when the individual nature of the estuary or coastal waters require such specificity.

Outstanding National Resource Waters

Some estuarine and coastal waters of the State may require special criteria based on unique characteristics of that waterbody. Such characteristics might include undisturbed or unique fjords or subestuaries or stretches of coastline that are markedly different from other coastal waters in the State. Some areas may include threatened or endangered species that need to be protected. Such waters are the very best of the reference set and are most in need of protection by rigid State and Tribal antidegradation policies and procedures.

Aquatic Life Uses

Aquatic life uses, including fisheries and shellfisheries, are heavily dependent on the initial high quality condition of the resource. Species will change as a function of trophic state, and it may be difficult to defend why one species is necessarily "better" than another. The use of reference areas and their accompanying biota is one measure that can be used to predict the species that should be expected in a region.

Fisheries

Developing criteria to protect a specific fishery may be somewhat difficult because in open estuarine and coastal waters fish species shift with seasonal migrations and salinity changes. However, basic response variables such as available DO and turbidity can be incorporated to protect all seasonal fish and crustacean communities and resident molluscan populations. Consultation with fisheries managers, the recreational public, and commercial fishermen should help resolve any issues of targeted species management through nutrient abatement.

Although our knowledge of the dynamics of change in the biota as a function of eutrophication requires further development, there is sufficient evidence to conclude that eutrophication will bring species changes. If an area has an existing aquatic life use, then that use must be maintained. (See 40 CFR §131.12(a) (1).) Eutrophication will cause some species to change in relative abundance and cause others to disappear; therefore, nutrient enrichment may be incompatible with the maintenance of a specific biota. The ultimate extension of this concept is in the use classification of outstanding natural resource waters.

Recreation

Swimming/Primary Contact Recreation

Criteria to protect a contact recreation use may be associated with the occurrence (or appearance) of certain phenomena that affect certain types of recreation. For example, in general, swimmers will not be affected by the trophic state of the estuary, but resulting changes in transparency or change in species may be important. Dense planktonic or macrophyte growth may inhibit swimming opportunities and help promote seasonal densities of sea nettles or "jelly fish." Excess nutrients feed not only nuisance algae growth, but potentially health-endangering bacteria, especially when human or animal waste may be involved such as when sewerage discharges are in the general area and may impact swimming when wind and tide coordinate. This risk is not unusual for coastal ocean beaches where development promotes sewerage expansion and offshore discharges.

Boating and Secondary Contact Recreation.
It might be expected that the transparency of the water or the presence of algal scums would not deter boating, unless water skiing were involved. However, boating may be affected by the presence of dense inshore beds of tall or floating macrophytes.

Restoration Goals

As described in the introduction to this chapter, designated uses may be protected but some nutrient-based ecological degradation already may have occurred. The public deserves to know what nutrient conditions existed before anthropogenic nutrient enrichment initiated a shift from the natural nutrient regime toward conditions of nutrient impairment within the limits of scientific knowledge or reasonable scientific inference.

Sampling for Comparison to Criteria

Once criteria have been selected for each indicator variable (e.g., as a minimum, TN, TP, chl *a*, or macroalgal biomass as AFDW and a measure of water clarity associated with chl *a* and, where appropriate, the addition of dissolved oxygen), States and Tribes will want to develop implementation procedures to assess the estuarine and coastal water with the criteria. Sampling to evaluate attainment with criteria and adopted standards should be compatible with the procedures to establish the criteria in the first place. If the criterion was developed for a particular season, then sampling should be compatible with that season. In some cases, it is plausible that nutrient concentrations will not correlate predictably with response variables because of estuarine hydrodynamics. In such cases, the useful relationship should be directed toward nutrient loading. Many published estuarine nutrient relationships are based on nutrient load, often normalized to estuarine surface area, not nutrient concentrations. In such cases, the sampling of load relative to response variable should be scientifically based on the appropriate season with consideration for appropriate time lags (see Chapter 2). In many cases, relationships will need to be sought through application of a computer model (see Chapter 9).

Questions will arise about the size of area, depth of sample, frequency, and duration of any exceedances. These are difficult questions but the RTAG must be prepared to address them. It is expected that scientific judgment will be required in numerous cases that pushes the state of the science and in some cases it may be necessary to make risk management decisions extend beyond the current state of science. Some illustrative examples are provided but should not necessarily be interpreted literally. If an area is small and does not limit life cycle completion of important species (e.g., deepwater hypoxia that may serve as a bottleneck to estuarine species migration), then some tolerance is accepted. However, if the duration and magnitude of noncompliance of a criterion lasts long enough to affect the distribution and abundance or recruitment of an important species or a key food web component at a designated level (e.g., 15% reduction in the population of a harvestable size class is estimated based on the best available judgment), then the criterion needs to be adjusted. In some cases, empirical or computer models will be required to address many of the more complex relationships.

The question arises, how many replicate samples are needed to obtain an acceptable precision of data in order to detect differences between sites and changes over time? This depends on the nature of the variability in the variable of interest. Several approaches are available. However, this question involves both statistical and practical considerations (e.g., cost). General experience suggests that field water quality sampling will often vary by 20%. With this “rule of thumb,” it may not be cost-effective to try to achieve a lower percent difference. Eckblad (1991) provides some guidance on statistical considerations in sampling power. The Kendall test with Sen slope estimate (Hirsch et al. 1982) allows the determination of the number of replicate samples needed to detect a certain percent change in annual means of a variable or a certain percent trend over a period such as 10 years (see Rivers and Streams Nutrient Guidance Manual (U.S. EPA 2000b, Appendix A).

7.8 NUTRIENT CRITERIA INTERPRETATION PROCEDURES

However done, a State’s or Tribe’s nutrient criteria should include a procedural protocol to implement the newly adopted nutrient criteria. The criteria and procedures should be reviewed by the RTAGs for concurrence and are subject to further EPA review and approval if submitted as part of State or Tribal standards.

The initial criteria variables include two causal variables (TN and TP) and two response variables (algal biomas, e.g., chlorophyll *a* for phytoplankton and AFDW for macroalgae) and water clarity (e.g., Secchi depth), and where hypoxia occurs, dissolved oxygen may be added as a third response variable. Failure to meet either of the causal criteria should be sufficient to indicate a criteria “excursion,” and usually the biological response, as measured by chlorophyll *a* and Secchi depth, will follow this nutrient trend. However, if the causal criteria are met but some combination of response criteria are not met, then there should be some means of determining if the waters in question meet the nutrient criteria. Two suggested approaches are described below.

Decisionmaking Protocol

One option is to establish a decisionmaking procedure equation all of the criteria. Such a rule might state: “Both TN and TP causal nutrient criteria must be met, and a least three out of five response criteria (e.g., water clarity, algal biomass as chlorophyll *a* or macroalgal biomass as AFDW, DO, seagrass or SAV biomass, and phytoplankton species composition) must be met for three out of four sampling events during the June through August survey period over 2 consecutive calendar years of sampling. No sampling events may be less than 3 weeks apart [to avoid clustering sampling activities near a particular flow condition or runoff event], and flow and tidal conditions must be recorded as well so that watershed base flow and runoff events are evident and can be factored into the data assessment process.”

Multivariable Enrichment Index

The second option is to establish an index that accomplishes the same result by inserting the data into an equation that relates the multiple variables in a nondimensional comprehensive score much the same way an index of biotic integrity (Karr 1981) does. An example of an enrichment index approach is presented in Table 7-1.

Table 7-1. Example of an enrichment index using the middle portion of a hypothetical estuary

Variable	Criterion	Hypothetical estuary or salinity zone of estuary	
		Median measured value	**Enrichment Index (EI) score***
Causal variables			
Total P (mg/L)	≤2.0	2.5	4
Total N (mg/L)	≤68	70	5
Primary response variables			
Secchi depth (M)	≥1.0	0.6	3
Chlorophyll *a* (mg/L)	≤60	75	3
Secondary response variables			
Dissolved oxygen (mg/L in hypoliminion)	≥6.0	3.5	4
		Enrichment Index Value: = 19**	

* Each of the eight variables receives an EI score. The scoring procedure is: 0 = meets criterion; 2 = fails to meet criterion by 10%; 3 = fails to meet criterion by 25%; 5 = fails to meet criterion by 50% or more.
** Enrichment Index Value is the sum of the EI scores. The maximum i.e. worst score achievable is 25.

If necessary, the scoring process can be weighted by seasons. Thus, different emphasis can be given to the results of winter surveys as compared with summer surveys, and year-round work can be conducted if necessary or desired. For example, greater weight perhaps by a factor of 2 could be given to the primary response variables in winter for north temperate waters because these variables would normally be expected to be improved at this time of year. Similarly, the criteria for TP and TN might both be changed to lower concentration for winter because less runoff or fewer fertilizer applications are expected in the watershed. In the example, the estuary or region thereof fails anyway because it failed the criterion for either TP or TN (in fact it failed both). With a score of 19 out of a possible 25, it is also a prime candidate for extensive remediation management.

Such enrichment index scores are not intended at this time to be surrogate nutrient criteria. They may, however, serve as a “translator” to implement multiparameter criteria. However, like biological criteria index scores such as the Index of Biotic Integrity, the enrichment index may be a useful assessment tool relating several parameters. This helps the resource manager plan the distribution of effort and funds over the entire estuarine or coastal resource base in one procedure.

Frequency and Duration

Frequency and duration are important concerns when evaluating any water with respect to meeting criteria. This is a difficult process at this initial phase of the program because the data sources for criteria development are presently so diverse. In general, however, the method of data gathering for compliance should be as near as possible to that used to establish the criteria, especially keeping in mind tidal phase and salinity. Once consistency is established, excursions from the criteria based on frequency and duration can be evaluated whether based on a decision rule or a multivariable index.

Frequency of “excursion” from a criterion is a decision that can be best established by the State or Tribe on the basis of their knowledge of the local water resources. An excursion that occurs less than 10 percent of the times when sampling is conducted (at regularly spaced or random intervals) may be considered acceptable. Duration of the excursion may be stipulated as a set period of time (e.g., 2 weeks, or as to not exist over more than two consecutive sampling intervals, whichever is the lesser period). The State or Tribe in consultation with EPA will need to specifically define these terms as appropriate to the region and should also determine the combination of these factors that constitutes an “excursion.”

7.9 CRITERIA MODIFICATIONS

Some situations may require site-specific criteria because of unique environmental conditions. In such situations, the general criterion is a starting point and it must be modified to protect designated uses in a unique situation. Such criteria can be adopted into State or Tribal water quality standards and reviewed by EPA.

7.10 EPA, STATE, OR TRIBE RESPONSIBILITY UNDER THE CLEAN WATER ACT

The Clean Water Act as amended (Pub. L. 92-500 (1972), 33 U.S.C. 1251, et seq.) requires all States to establish designated uses for their waters (Section 303(c)). Designated uses are set by the State. EPA’s interpretation of the CWA requires that wherever attainable, standards should provide for the protection and propagation of fish, shellfish, and wildlife and provide for recreation in and on the water (Section 101(a)). Other uses identified in the act include industrial, agricultural, and public water supply. However, no waters may be designated for use as repositories for pollutants (40 CFR 131.10 [a]). Each waterbody must have criteria or measures of appropriate water quality that protect and maintain the designated use of that water. It is recommended that the EPA nutrient guidance be followed. However, States and Tribes may follow other guidance to adopt water quality criteria as long as the criteria are based on scientifically sound methods and protect designated uses.

7.11 IMPLEMENTATION OF NUTRIENT CRITERIA INTO WATER QUALITY STANDARDS

Nutrient criteria adopted into water quality standards by States and Tribes are submitted to EPA for review and approval (see Section 40 CFR 131). EPA reviews the criteria (40 CFR 131.5) for consistency with the requirements of the CWA and 40 CFR 131.5, which requires that water quality criteria be sufficient to protect the designated use (40 CFR 131.6 (c) and 40 CFR 131.11). The procedures for State/Tribal review and revision of water quality standards, EPA review and approval of water quality standards, and EPA promulgation of water quality standards (upon disapproval of State/Tribal water quality standards) are found at 40 CFR 131.20-22. The Water Quality Standards Handbook (U.S. EPA 1994) provides guidance for implementation of these regulations.